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THE CORRELATIONS OF THE OF THE PARTICLE SIZE, CALORIFIC VALUE, MOISTURE- AND ASH CONTENT OF WASTE DERIVED FUEL, AND EXAMINATION OF ITS HEAVY METAL CONTENT

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ABSTRACT

Significant development has taken place in the field of waste management recently in the preparation of the energetic exploitation of recyclable, non-hazardous municipal solid waste. With mechanical-biological waste treatment, 35-40% of the weight of this waste can be made appropriate for energetic exploitation, mainly for co-incineration in cement factories and power plants.

The recoverability of waste derived fuel produced in mechanical-biological waste treatment plants highly depends on the burning and combustion technological properties of the mixture, and on its compounds influencing burning and different emissions. Waste recovery facilities do not take over fuel below a specific calorific value and over a given heavy metal, halogen and pollutant content.

In our research we were looking for correlations in the particle size, calorific value, moisture-, ash- and heavy metal content of waste derived fuel. On the basis of the measurement results, the connection between the particle size fractions and the fuel properties can clearly be stated. The fractions of smaller particle size have higher moisture-, ash- and heavy metal content, while the fractions of bigger particle size have higher calorific value.

Keywords: mechanical-biological waste treatment plant, RDF, SRF, particle size, calorific value, ash content, heavy metal content

1. INTRODUCTION

WDF (waste derived fuels) from non-hazardous waste, produced through mechanical-biological waste treatment of mixed residual waste remaining from selective waste collection, are refuse derived fuel (RDF) and solid recovered fuel (SRF).

According to the research report of Ecoprog, the amount of the RDF/SRF produced within the EU (European Union) is continuously growing. By 2025, the expected mechanical biological treatment (MBT) capacity will have reached 65 million tons. [1] 25 MBT facilities were established in Hungary between 2010 and 2015. In 2017 there were 31 MBT facilities, having an overall capacity of 1.65 million tons. [2]

RDF/SRF typically consists of plastic, paper, textile and other combustible materials [3]. It is characterized by higher calorific value, more homogeneous physical-chemical composition, easier storage, handling and transport, and lower pollutant emissions compared to the energetic exploitation of mixed municipal solid waste (MSW). [4] The quality of waste derived fuel is generally characterized by homogeneity, composition, energy efficiency, calorific value, moisture-, ash-, sulphur- and chlorine content and heavy metals. [5] [6] Moisture content is a critical parameter that affects all other SRF quality-characteristics, but mainly calorific value. [7] The removal of interfering substances or not combustible materials, such as glass and inert matter, however, has a positive effect on calorific value. [8]

Fuel generated in the course of mechanical treatment is handed over for energetic exploitation through incineration or gassing. Handling temperature shows significant difference between the two technologies. Incineration takes place at 850-1000 °C, gassing at 1200-1400 °C. Heavy metals in the fuel undergo a transformation in the process of incineration, and they get into the waste gas and ash generated in the course of energetic exploitation. To ensure their safe and effective usage, appropriate disposal or treatment procedures should be applied. [9] [10] [11]

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In addition to the above-mentioned technologies, fuel is also used in cement factories for co-incineration all around Europe, where incineration takes place at 1400 °C. In these cases, ash is incorporated in the finished product, so it is of particular importance that the incorporating substance does not downgrade the quality of the finished product. [3] [12]

In practice, the exploitation of RDF/SRF can take place in other various ways. The possible environmental impact of residual-ash incorporated in roadbeds was examined, compared to dumping broadly considered as the worst option. [13] To these alternative forms of utilization, it is also necessary to have a detailed examination of the treated ash to know its chemical properties (metal content, pH), since it is often used in the ground-level where migration and leak characteristics are also of great importance. [10] [14]

Test measurements were also made to bond metals in the fuel in chemical or physical form using added substances in the course of utilization; but four out of the tested elements could not be bonded with any of the substances, and they all got to the ash. [15] These properties are determined not just by the fuel production technology, but also the composition and quality of the incoming material of the mechanical treatment plays a significant role in it. [3] [16] Additives, coatings and alloys of packaging materials and hazardous waste have the biggest effect on the heavy metal content. [17] [17] [19] One part of these wastes is collected separately in an ideal case, but due to the residents they often get to municipal waste, and they significantly affect the parameters of the generated fuel. [16]

In Hungary, several researches were done over the last few years to ensure a higher quality of waste derived fuel. In Miskolc, experiments were carried out in the fields of developing fractions of high calorific value, separating metals more efficiently and pelleting fuel. [20] Some other research teams examined the composition of the incoming mixed residual waste at MBT, its particle size distribution, weight distribution, composition ratio and calorific value. [21] [21] [23] [24] Also, the development and testing of some combined separation equipment suitable for the increase of the efficiency of fuel production is in progress. [25]

2. MATERIALS AND METHODS

In Pécs, mechanical-biological waste treatment procedures are applied for the non-hazardous mixed municipal solid waste (MSW). The research was carried out in the mechanical-biological waste treatment plant at the Regional Waste Management Centre of Pécs-Kökény, and we studied the waste-derived fuel generated there.

From the residual, mixed MSW of SRF production, interfering substances are removed by manual pre-selection and then the waste is shredded to particle size of less than 350 mm with the help of a pre-shredder. The waste stream contains recyclable, combustible and inherently biodegradable components. From the shredded stream of material, magnetic metal is detached, then the fraction of high biological content is separated through a trommel with a mesh of 60 mm. From the upper fraction of the trommel (>60 mm) magnetic and non-magnetic metal is separated by the eddy current separator. The remaining stream of material goes through an air classifier that separates not combustible inert (stone, brick, concrete, glass) and other heavy materials. The combustible stream of material is then transferred to the post shredder where it is shredded to an average particle size of <60 mm. After shredding, a final magnetic metal separation takes place, and RDF/SRF is placed in the buffer container or directly transported.

In our experiments, the freshly generated fuel was divided into five different particle size ranges: <10 mm, 10 mm – 20 mm, 20 mm – 30 mm, 30 mm – 40 mm, >40 mm. In the measurements the ranges were examined separately. In each case, the measurement series was carried out on an original sample without sifting. When selecting the research categories and parameters, we used the physical and chemical parameters of Annex "A" of Standard EN 15359 as the basis. Among others moisture content, calorific value, ash content and heavy metal content of 11 elements were examined.

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2.1. Moisture content

The moisture content measurement was carried out by using the drying oven method. Representative samples were taken from the separated particle size fractions and from the raw unsifted material (<60mm), and the samples were dried to constant weight for 24 hours in a drying oven type POL-EKO-APARTURA SLW 400 STD. Further measurements were taken on the dried samples obtained.

2.2. Calorific value

For measuring the calorific value, bomb calorimetry method was used. To ensure the representativeness of the samples, the reduction of the particle size was needed. To improve the accuracy of measurement, the samples chopped to particle size of <10 mm were measured after pelleting. The wet and dry calorific value was calculated according to the requirements of the standard MSZ EN 15400:2011 using hydrogen correction.

2.3. Ash content

The ash content measurement was carried out according to the standard MSZ EN 15403:2011 using muffle furnace method. For the measurements the dried samples were chopped to an average particle size of <1 mm to ensure homogeneity, and they were put into a muffle furnace in heat-resistant ceramic cups. The calcination of the samples took place in two steps with the parameters given in the standard: first at 250 °C for 60 minutes, then at 550 °C for 120 minutes.

2.4. Heavy metal content

During the measurements, the heavy metal content of the fuel was determined by using the method of inductively coupled plasma optical emission spectrometry (ICP-OES). The samples of waste derived fuel were dried to constant weight (when its mass is constant) and chopped to an average particle size of 0.25 mm to ensure homogenisation. Through chemical degradation, 0.25 g sample was put into solution by using ultra-pure chemicals. During the measurements, we derogated from the standards in so far as we not only used hydrochloric acid (HCl) and nitric acid (HNO_3) as reagents but also hydrogen peroxide (H_2O_2) so that the oxidation of organic matter can take place easier. The mixture of the same chemicals was used at the blind samples in order to get as accurate test results as possible. After degradation the aqueous solutions were diluted, and ICP-OES measurements were done on these for the following 11 heavy metals: antimony (Sb), arsenic (As), cadmium (Cd), chrome (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), thallium (Tl), vanadium (V). The concentration found in the aqueous solution was then calculated back referring to mg/kg dry SRF.

3. RESULTS AND DISCUSSION

3.1. Moisture content

Figure 1. shows the average result of the 49 samplings. The measurement results clearly indicate that the moisture content is inversely proportional to the particle size. The moisture content of the fraction with the smallest average particle size is twice as high as that of the fraction with the biggest average particle size, because they contain high levels of biodegradable organic material. The original sample without sifting showed similar quantities to the results of the sample with average particle size of 20-30 mm.

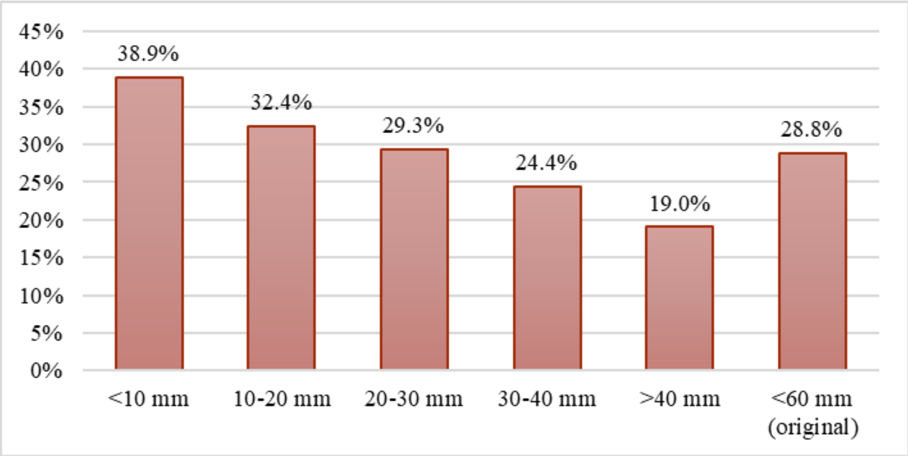

Figure 1. Changes of the moisture content depending on the particle size. [w/w%]

3.2. Calorific value

Figure 2. depicts the changes of the dry calorific value depending on the moisture content as the average of 24 samplings. It can be clearly seen that the calorific value is directly proportional to the particle size. In this case, the result of the original sample without sifting is most similar to the results of the fraction of 20-30 mm.

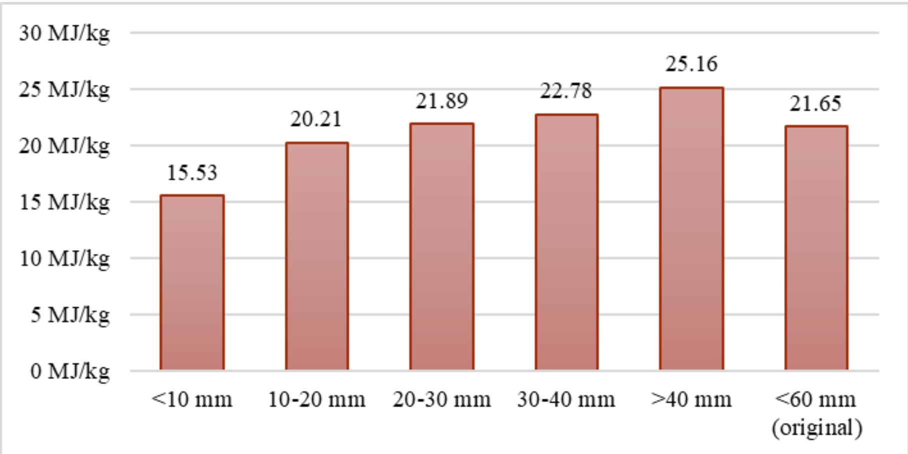

Figure 2. Changes of dry calorific value depending on the particle size. [MJ/kg]

Figure 3. illustrates the changes of wet calorific value depending on the particle size. These are the results of the calculations made according to the standard already containing the corrections with moisture content and hydrogen content. In this case it can be clearly seen again that the calorific value is directly proportional to the particle size.

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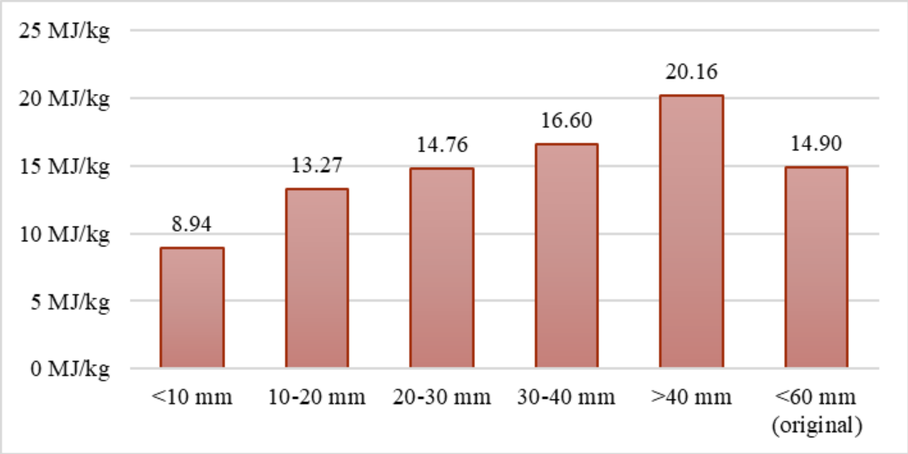

Figure 3. Changes of wet calorific value depending on the particle size. [MJ/kg]

3.3. Ash content

Figure 4. shows the average result of the 36 samplings. The results indicate that the ash content is inversely proportional to the particle size. This is probably due to the fact that the inert part of the waste with fine particles accumulates in the smaller fractions.

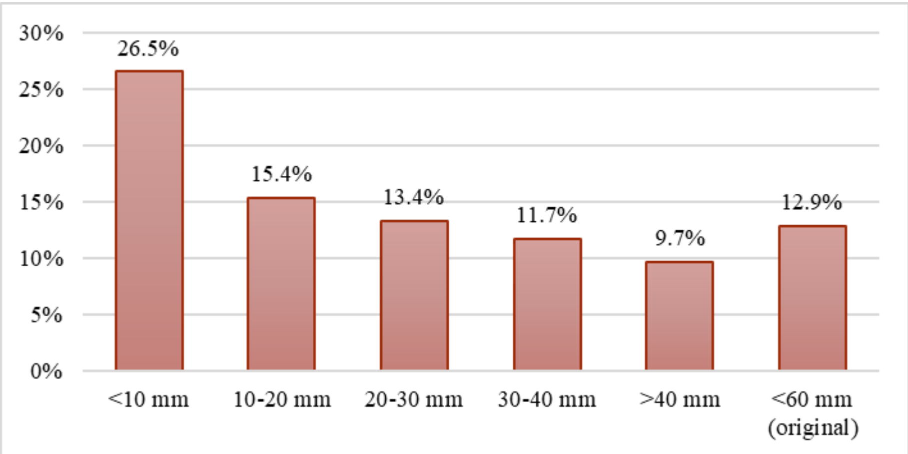

Figure 4. Changes of the ash content depending on the particle size. [mg/kg]

3.4. Heavy metal content

Figure 5. contains the total heavy metal content. It can be seen, that similarly to the ash content, this parameter is also directly proportional to the particle size.

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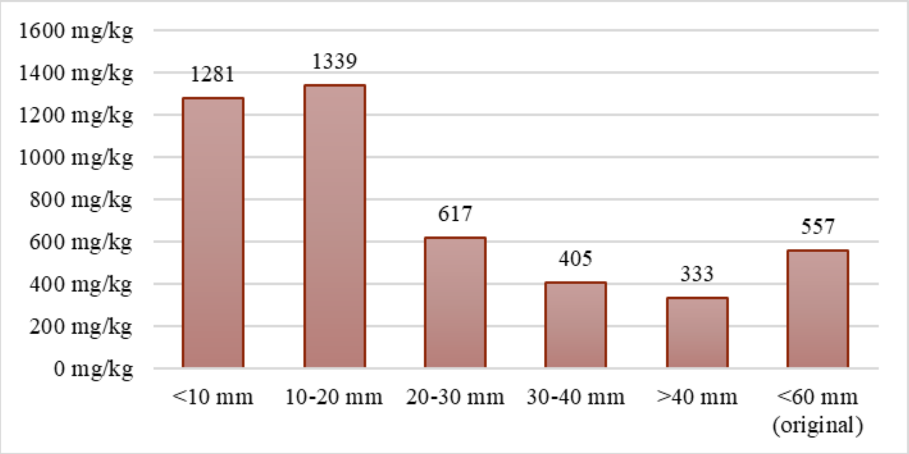

Figure 5. Total heavy metal content depending on the particle size. [mg/kg]

The proportionality is not so clear here as in the case of the other tested elements. At the fraction with 10-20 mm particle size, the total heavy metal content is bigger than at the fraction with an average particle size of <10 mm. When examining the results of the tested heavy metals, it emerges that the same trend is observed in the case of copper content, as it can be seen in Figure 6. In order to exclude incorrect measurement results, we examined the sample before homogenisation, and in all 3 cases significant amount of copper line remnants were found. During mechanical treatment, the plastic coating of the copper wires faultily thrown to MSW get damaged, the wires can break into smallish pieces, and they typically appear in larger amount in this particle size.

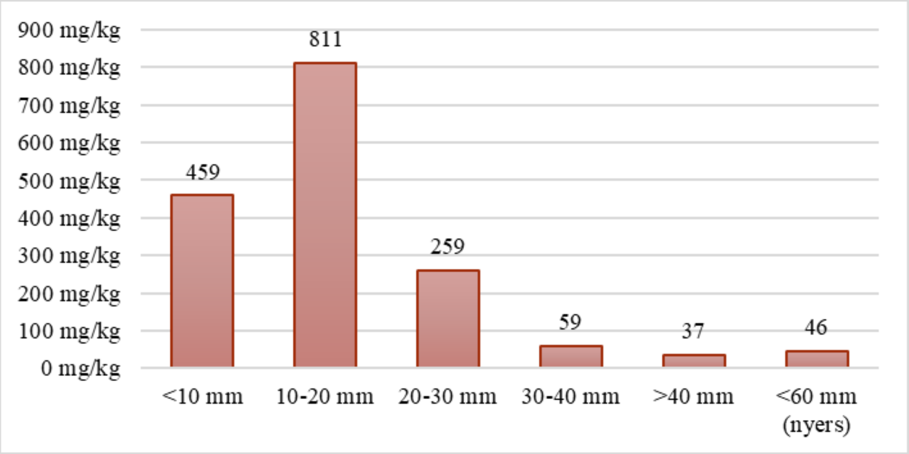

Figure 6. Changes of the copper content depending on the particle size. [mg/kg]

4. CONCLUSIONS

In our measurements we examined fuel generated in the Regional Waste Management Center of Pécs-Kökény. The measurements were performed according to Annex A of Standard EN 15359. In brief, the measurement results can be summarised as follows.

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Figure 7. depicts if calorific value is compared to moisture content, moisture content has a negative effect on calorific value, since the two measured properties show inverse proportion. Therefore, if we want to increase the calorific value of the output material, it is likely to be reached with the reduction of the moisture content. This could be achieved by using the natural drying period of the material, when it is stored in a covered area, where it is protected from the unsuitable weather conditions like rain and fog.
The biggest influence factor, when it comes to both the quality and quantity of the final product, is the incoming material, after all, the MBT plant is only there for to process the incoming waste stream. If anything changes in the incoming material, for example more people start to collect separately the packaging waste or the green waste, it will have an effect on the output material. Growth in the separate collection of the green waste would have a positive impact on the quality of the RDF/SRF as this group of substances has a significant influence on moisture content, that is in correlation with the aforementioned important chemical and physical properties. In contraire, growth in the separate collection of the packaging waste would have a negative impact on the quality and the quantity of the RDF/SRF, because most of the materials that have the best combustion properties are packaging materials.

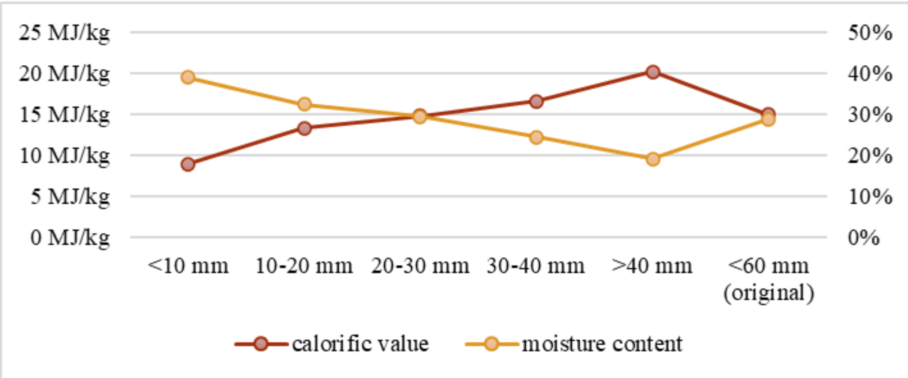

Figure 7. The comparison of the changes of calorific value and moisture content. [w/w%; MJ/kg]

When calorific value is compared to the previous tests, it becomes clear that it shows an inversely proportional relationship both with moisture content and with ash content. This can be seen in Figure 8. In the light of practical experience, fractions with smaller average particle size contain inert and biodegradable material in a higher percentage, and these cause the higher ash- and moisture content.

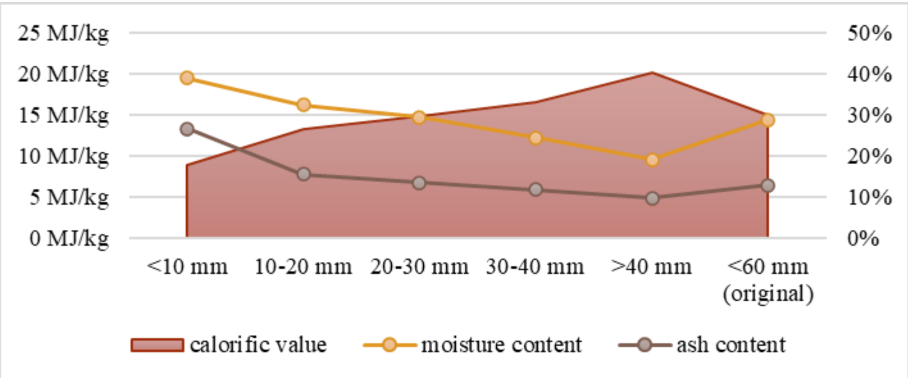

Figure 8. Changes of the calorific value, moisture content and ash content. [MJ/kg; w/w%]

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In search of further relationships with ash content, we found that there is a relationship between the two parameters when compared with heavy metal content. The results shown in Figure 9 let us conclude that materials containing heavy metals can be found in a higher percentage in the fractions with smaller particle size.

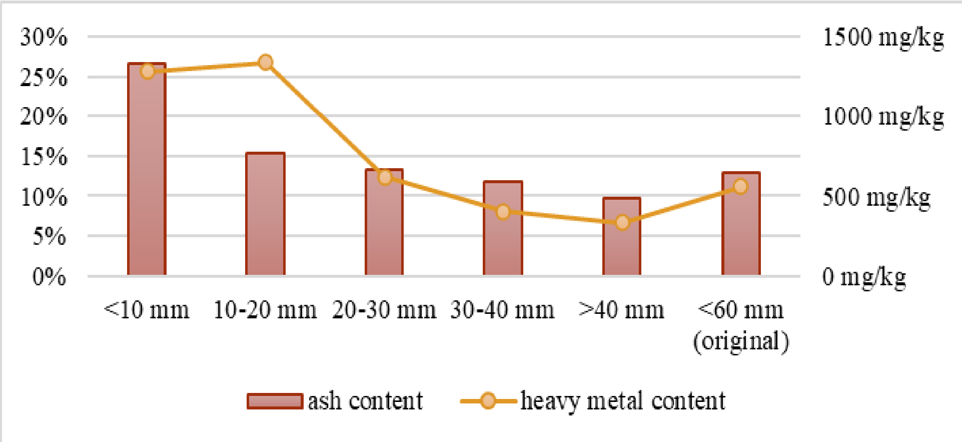

Figure 9. Changes of the ash content and the total heavy metal content. [w/w%; mg/kg]

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